Strategic Plan: 2001-2005
NOAA Forecast Systems Laboratory
April 2001

1. Introduction

Forecast Systems Laboratory (FSL) became a NOAA Research laboratory on 23 October 1988. In the thirteen years since its inception, FSL has had an extraordinary record of accomplishment in its mission of transfer of science and technology to the National Weather Service and other organizations. This Strategic Plan is an outgrowth of many discussions within FSL from July through September 2000 and represents a consensus of FSL staff. The plan is consistent with the strategic plans of NOAA (http://www.strategic.noaa.gov/) and OAR (http://www.oar.noaa.gov/organization/, click on “NOAA Research Backgrounders”), our parent organizations, and with those of the National Weather Service (NWS) (http://www.nws.noaa.gov/sp/) and the National Centers for Environmental Prediction (NCEP http://www.ncep.noaa.gov/ click on “NCEP Strategic Plan”), with whom FSL interacts regularly.

2. FSL Mission

1) Mission statement

FSL transfers new technology and research findings in atmospheric, oceanic, and hydrologic sciences to other NOAA offices and other users of environmental information. It conducts programs, involving the following activities, to evaluate, integrate, and apply these developments to environmental information and prediction systems:

- *Exploratory System Development* – Anticipate requirements for NOAA’s operational services and develop concepts in cooperation with operations specialists to meet these requirements. Test the utility of these concepts in environmental information and prediction systems for operations and data management.
- *Research Applications* – Conduct applied research toward improved forecasting capabilities. Capitalize on technological advances and improved understanding of the atmosphere-land-ocean environment to develop improved techniques for geophysical observations, more effective data assimilation, and more accurate prediction models.
- *System Validation* – Use real-time and archived data to test and evaluate hardware and software systems and their diagnostic and predictive output.
- *Technology Transfer* – Work directly with users in expediting the transfer of new techniques and systems to operational use. Work toward effective dissemination of environmental information to foster highly informed decision-making.

2) Accomplishments

FSL has a record of success in these areas. Most prominent of accomplishments is the major support it provided in the development and implementation of the NWS Advanced Weather Interactive Processing System (AWIPS http://www.nws.noaa.gov/msm/awips/awipsmsm.htm). FSL spearheaded efforts to make wind profiling (http://www-dd.fsl.noaa.gov/profiler.html) and ground-based, Global Positioning System (GPS) moisture observations (http://www-dd.fsl.noaa.gov/gps.html) a staple in regional prediction. Taking advantage of more powerful computers to improve forecasts, FSL developed and operationally implemented the Rapid Update Cycle (RUC http://maps.fsl.noaa.gov/), which generates new analyses and short-range forecasts hourly for aviation and other interests. Additional benefits to forecasters came with the implementation on AWIPS computers of a version of the Local Analysis and Prediction System (LAPS http://laps.fsl.noaa.gov), which gives forecast offices nationwide the means to analyze local data sources, and the Mesoscale Analysis and Prediction System (MAPS) Surface Assimilation System (http://www-sdd.fsl.noaa.gov/MSAS/msas.html), a tool for checking and analyzing surface observations. Modelers welcome FSL's pioneering techniques for adopting large computational programs to run on highly parallel computer architectures (http://armstrong.fsl.noaa.gov/ac/). FSL experts have long been active in educating field forecasters about new observing systems and models, either directly or through the Cooperative Program for Operational Meteorology, Education and Training (COMET©). For a sampling of recent FSL activities, consult the *FSL Forum* at http://www.fsl.noaa.gov/docs/publ/forum1296/Forum.html or *FSL in Review* at http://www.fsl.noaa.gov/~vondaust/fir99/.

3. Areas of Focus

In the coming five years, FSL will focus on five areas:

- Environmental information systems
- Observing systems
- Numerical weather prediction
- Advanced computing
- Collaborative program development

Strategies within each of these areas seek to capitalize upon existing areas of expertise, while serving the common themes of technical leadership and effective service to a wider community. Many of these strategic elements embody logical extensions to past achievements. All derive from the fundamental technology transfer mission of the laboratory.

1) **Environmental information systems**

VISION

FSL plays a leading role in applying technology and research to the design, demonstration, and evolution of environment-related operational systems. Effective technology transfer is achieved through a combination of internal expertise and continuing emphasis on direct interaction with the operational community. These systems

- perform real-time acquisition, integration, and display of environmental data
- support data analysis and forecasting operations
- disseminate forecasts and data to end users.

The systems are designed to be effective in real-time, highly demanding operational environments.

REALIZING THE VISION

- Generalize systems.
  The traditional focus of FSL systems has been on NWS operations and weather forecasting systems. FSL can more effectively transfer technology by generalizing its systems to support a wider community of users.
  - Move toward highly modular system architectures comprising generic services that are customized to support particular operations.
  - Emphasize higher levels of system-level extensibility and configurability.
  - Expand operational context to a variety of environmental systems and data types.
  - Consider worldwide localization issues.

- Support evolution.
  Foster evolutionary change in operational systems to avoid the need for massive system modernization programs.
  - Migrate systems toward standard, cost-effective platforms.
  - Utilize Web technology to provide more sophisticated levels of dissemination.
  - Investigate new ways of generating and presenting meteorological information.
  - Seek cost-effective ways to increase operational site capacity.
  - Investigate improved ways of acquiring, validating, integrating, and presenting data.
  - Investigate the application of wireless technology as it matures.

- Facilitate collaboration.
  Make it easier for FSL research partners to use our software and data on a variety of computers.
  - Define and support system configurations and off-the-shelf software packages for laboratory-wide demonstration and prototyping use.
  - Furnish simple mechanisms for real-time data acquisition and access to retrospective datasets.
  - Provide a method for extending systems with new applications, displays, and data types without requiring rebuilds of the base system.
  - Provide a complete set of Web-based documentation describing demonstration/ prototyping platforms and software, data loading facilities, and extensibility.
  - Expand the use of Web-based discussion forums.

2) **Observing systems**

VISION

FSL plays a major role in the conception, design, testing, and use of meteorological observing systems. These efforts make a significant, positive contribution to the observing system of the 21st Century. Emphasis will be on integrated observing systems employing a range of sensors and measuring systems.

REALIZING THE VISION

- Observing system concepts
  - Work with other NOAA agencies and federal laboratories to specify and optimize the environmental observing system serving our continent.
  - Advocate an integrated observation system composed of subsystems that have demonstrated economic, operational, and scientific suitability.
  - Work with appropriate partners to investigate new technologies and approaches to measuring atmosphere parameters.

- System design
  - Work toward perfecting designs of systems presently in experimental or prototype stage, such as: the Global Air-ocean IN-situ System (GAINS) of high-altitude balloons, the Regional Radar Volume (RRV) of data from the NWS Doppler radars (WSR-88D), automated reports from commercial aircraft (e.g., ACARS, MDCRS, and AMDAR), and the GPS-Met Demonstration Network of widely spaced, dual-frequency GPS receivers.
  - Develop and use state-of-the-art techniques for archiving, accessing, and displaying quality controlled datasets.
  - Investigate the use of signal delay along each GPS satellite/receiver path in an assimilation system to infer water vapor distribution.
  - Develop new uses for NOAA Profiler Network data, routinely collected but not presently used in mesoscale analysis and assimilation.
  - Continue advocacy for observations collected by organizations outside of NOAA, including local, state, and federal agencies and private firms. Offer reliability and quality control information to data providers as an incentive for providing their data to NOAA.

- System testing
  - Operate a suite of observing systems and combine their output with that of other operational and research systems to form a dataset that can be used to test various assimilation and forecasting approaches.
  - Test and verify the GAINS concept through a series of long-range, high-altitude balloon flights.
  - Participate in field experiments of opportunity to test and demonstrate the capabilities of prototype observing systems.

- System use
  - Operate FSL observing systems, such as the NOAA Profiler Network, routinely to provide a dataset useful to operations, research projects, and ongoing FSL activities to improve modeling and forecasting.
  - Embrace a global view of observing systems through the expansion of regional model domains over the oceans. Address the problem of sparse in situ data upstream from the West Coast through consideration of oceanic satellite observations. Increase involvement in global observing problems, especially by finding ways for new observing systems to complement existing ones.

3) Numerical weather prediction

VISION

FSL performs research toward development of advanced operational systems that:
- use a computer model to produce a weather forecast
- assimilate observations to provide initial conditions for the forecast
- verify in detail the accuracy of the forecast.

REALIZING THE VISION

- Develop modeling and assimilation techniques to support improvements in the following application areas:
  - nowcasting
  - severe weather watches and warnings
  - quantitative precipitation forecasts on time scales from one hour to three days
  - water management, emphasizing precipitation and runoff in small and medium sized basins
  - forecasting and monitoring for air quality and other regional environmental problems requiring coupled models (as defined under the next bullet)
  - fire weather forecasting
  - regional climate simulations and forecasting
  - design of observing systems

- Pursue the following specific modeling-related techniques:
  - diabatic initialization on the mesoscale
  - coupled models: full interaction between atmospheric dynamics/physics and additional components involving the land surface, oceans and lakes, hydrology, chemistry, and biology
  - advanced parameterizations of small-scale processes including convection and turbulence
  - advanced data assimilation methods
  - improved understanding of phenomena through diagnostic use of models and assimilation systems
  - incorporation of mesoscale observations through data assimilation at sub-hourly frequency
  - efficient computing with moderately or massively parallel computers
  - new techniques in model verification, especially at the mesoscale

- Establish a real-time ensemble forecast capability to quantify the uncertainty in forecast accuracy, estimate situation-dependent forecast errors, and assess the value of the ensemble mean as compared to the value of a single higher-resolution forecast.

- Maintain a strong quality control program for all observational datasets utilized by data assimilation systems, and provide the observations, quality control information, and data access software to assimilation researchers through FSL’s Assimilation Model Experiment (FAME) project.

- Maintain a strong verification program embracing not only direct model output, but also products derived from model output, especially for important weather data user groups such as aviation.

- Further reduce the number of forecasts with serious errors and exploit such cases to improve modeling/assimilation capabilities.

4) Advanced computing

VISION

FSL strives to be a leader in high-performance computing, providing essential infrastructure for weather and other environmental research.

REALIZING THE VISION

- High-performance computer architecture
  - Lead NOAA in investigating new computing technologies and proving their utility.
  - Demonstrate capabilities of FSL's HPTi computer.

- Scalable model tool development
  - Move the Scalable Modeling System (SMS) towards the next-generation advanced computing architecture.
  - Use SMS to parallelize new or existing ocean, climate, and atmospheric models (e.g., Weather Research and Forecasting (WRF) model) and their associated data assimilation systems.

- Infrastructure for high-performance computing
  - Develop user-friendly access tools for high-performance computers.
  - Support operational and research sites running models both internally and externally.
  - Investigate emerging network technologies to support all aspects of the high-performance computing environment.
  - Develop data management capabilities to improve data access and metadata handling.

5) Collaborative program development

VISION

FSL strives always to be in step with its customers and to anticipate and respond to their needs in an ever-changing technological world.

REALIZING THE VISION

- New Program Development
  - Pursue funding opportunities for new programs and projects with domestic and

international research and operational groups within government, educational institutions, and the private sector.
- Pursue increased project activity in environmental modeling that involves coupling models for atmospheric motion, air chemistry, ocean, and ground hydrology; model regional aspects of climate change.
- Increase interactions with NWS field offices and their Regional Headquarters in the areas of training, mesoscale model execution, Web design, test beds, and field requirements.

· Collaboration
  - Increase interdivisional collaboration within FSL.
  - Increase collaboration in FSL areas of expertise with other NOAA laboratories, external research laboratories, the university community, international groups, and the private sector.
  - Provide a facility for outside researchers to use FSL's modeling and data assimilation software with observational data that FSL supplies in easy-to-use formats, thereby broadening the test base for product improvements.
  - Participate in the activities of the NOAA/NASA Joint Center for Satellite Data Assimilation.

· Education in support of program development
  - Develop a Web site highlighting collaborative project opportunities at FSL.
  - Provide a "center of expertise" education site on the Web page. Update this page with all new technology and science developed with or without collaborative partners.
  - Enhance environmental science education through print media: *FSL Forum, FSL in Review*, and brochures/fliers on all major projects. These handouts benefit teachers, students, the public/private sector, and the science community at large by providing concise but in-depth information for those with or without Internet access.
  - Seek significant improvement in FSL's peer-reviewed publication record, and provide Web-based access to laboratory publication materials.

4. Infrastructure

Activities that directly support FSL's technology transfer mission depend heavily on a number of underlying services that are often supported as laboratory infrastructure. Strategic goals related to infrastructure center around providing effective service both to groups within the laboratory and to collaborating groups outside the laboratory.

An essential part of FSL's strategic plan is to maintain expertise in technical areas that support laboratory, division, and project infrastructure. Much of FSL's infrastructure depends heavily on technology, and must thus routinely be upgraded to maintain currency. The selection, configuration, and maintenance of technology, and the ways in which services are provided, all focus on providing timely, efficient, and cost-effective service.

The following types of infrastructure are supported:

- High-performance computing
  Computationally intensive activities depend upon high-performance computing resources. Computational capacity, network bandwidth, and data storage requirements are extensive.

- Data accessibility
  Many activities depend upon the availability of environmental data. The acquisition, management, and accessibility of data are all relevant. Support of adequate network bandwidth and data storage capacity are critical to effective service.

- Computing facilities
  Workstations used for research, software development, communication, and administration are FSL's most essential tools. A reliable, secure network is an essential part of these facilities.

- Internet resources
  The Internet is increasingly the most effective means of communicating with sponsors, collaborators, and the public.

- Demonstration resources
  Resources are made available to support daily weather briefings; to demonstrate the capabilities of FSL systems, models, applications, and tools; and to support participation at science conferences, shows, and exhibits.

- Administrative support
  Administrative support to program managers and staff is an essential function. This includes budget and financial, personnel, procurement, space, property, security, contract management, and other forms of support.

5. Specific Goals

The following goals have been set internally by laboratory employees. They are designed to cut across divisions and to draw upon many areas of expertise within the lab (recall Section 2, “Areas of Focus”). FSL intends to exert its best efforts in reaching these goals, but the dates are to be considered ambitious targets. Future experience or budgetary fortunes may dictate that the dates be changed, the goals modified or abandoned, or new goals adopted.

1) Foster collaboration both internally between divisions and externally with new sponsors, and broaden the scope of FSL activities to include a variety of environmental data in addition to atmospheric weather data.

   Benefits: Through collaboration, FSL, the public, and our research partners all gain a more efficient and universally applicable means of accessing, analyzing, and using environmental data. Considering a more inclusive set of environmental data supports the increasingly interdisciplinary nature of environmental studies. Such a broadened horizon and collaboration foster a synergy of inter-disciplinary ideas, improved science, and an ability to use work done elsewhere to improve services, systems, and productivity.

- Migrate systems to inexpensive, widely available platforms that are more amenable to use by a wide variety of sponsors and users. Target all new development to be portable to Linux by the end of FY 2001.

- Through the FAME project, provide quality-controlled observations and data access software to university and government data assimilation researchers. (FY 2001 through FY 2005).

- Use the Web as a common means of furnishing documentation to, and encouraging feedback from, external sponsors and users. Establish guidelines for documentation by the end of FY 2001, and target full compliance by the end of FY 2002.

- Add or strengthen Web-based forums, as appropriate, to encourage feedback on product performance and project collaboration by FY 2002.

- Establish new collaborations by involving all divisions, jointly or separately, in a number of pilot or other cooperative projects involving new sponsors and/or new types of environmental data and associated operations. Seek a variety of sponsorship, including international organizations, government agencies, and commercial firms (end of FY 2002). Regarding international programs:
  - Leverage experience and knowledge gained from two successful international projects (Taiwan Central Weather Bureau and Korea Meteorological Administration) to improve short-term weather forecasting in additional countries (FY 2002).
  - Establish NOAA-developed meteorological and hydrological training programs in several international agencies (FY 2003).
  - Develop the FSL Worldwide Weather Workstation supporting improved information for synoptic and mesoscale weather forecasts and early warnings of severe weather events to international customers (FY 2004).

- Modularize and generalize software into components that can be more readily shared among projects and sponsors. Shape these components into an extensible framework for prototype development by FY 2005.

2) Support a smooth evolution of NWS operational systems through exploratory research, through demonstration and risk-reduction activities, and through direct support of technology transfer into operations.

   Benefits: The tools made available to NWS operations staff will allow them to more fluidly assess and predict the state of the atmosphere, and to more efficiently and effectively convey that information to the public. Improved timeliness, focus, and accuracy of weather information will benefit society and address the Weather Service's primary goal of saving lives and property.

- Validate methods of generating and disseminating modernized visual products and datasets (FY 2002). Extend this to demonstrations of the viability of a completely grid-based forecasting and dissemination system by FY 2005.

- Demonstrate a state-of-the-art system that supports NWS forecast and warning operations (FY 2003).

- Develop a path to operations for the Real-Time Verification System (RTVS) in support of NWS operational forecasting and warning goals (FY 2003).

- Be fully and continuously engaged in exploratory development that targets transfer to operations five to ten years into the future (FY 2003).

3) Improve FSL's network, data acquisition, data processing, and data management to keep pace with the data demands of new observing systems, data assimilation, and higher resolution advanced models.

   Benefits: Accomplishing this goal will provide a foundation for improved forecasting capabilities, which will benefit both the research and operational forecasting communities.

   In accordance with the FSL IT Architecture Plan, utilize resources and technologies to:

- Implement network monitoring capabilities and complete an upgrade to FSL's internal network and connection to the Internet by the end of FY 2002, in order to provide network performance that stays ahead of FSL's mission needs.

- Improve data management by implementing generic data processing techniques, upgrading interprocess communication services, implementing a metadata management system, and automating retrospective data processing capabilities by the end of FY 2003.

- Specify, implement, and utilize the two planned upgrades to Jet (the HPTi high-performance computer) by the end of FY 2002.

4) Develop a coordinated testbed for mesoscale observing systems. This would be a two-step process, initially comprising existing subsystems located in the central United States. This initial test bed would include the NOAA Profiler Network, FSL GPS-Met Demonstration Network, the Department of Energy Cloud and Radiation Testbed (CART) site, Oklahoma Mesonet, NWS radiosonde network, and other existing observing systems. Enhancements would be included as resources allow and would involve expansion to wider geographic areas as well as new or improved observing systems. This testbed will be used to provide a laboratory-like environment for short-term, high-resolution weather forecasting in which the observations are used both subjectively and quantitatively.

   Benefits: The rich data set will provide extensive ground truth for verification. Significant benefits will accrue to agriculture, transportation, construction, outdoor entertainment, and other sectors of the economy that can be adversely affected by weather. In addition, lead times will be improved for public warnings of severe or hazardous weather.

· Set up the organization and agreements with other agencies for this coordinated mesoscale testbed by the end of FY 2001.

· Employ a high-resolution model, chosen from existing models within FSL, to use this dense mesoscale dataset in case studies to determine high-resolution short-term forecasting limits by the end of FY 2003.

· Conduct sensitivity tests, simulations, and field evaluations to characterize the contribution of various observing systems to improved weather services. This continues through the end of FY 2005.

5) Develop improvements in short-range forecasts used for tactical planning, emphasizing accuracy in the timing, amount, and type of precipitation. Accomplish this in collaboration with other agencies, organizations, and institutions, and incorporate the insights and recommendations of the U.S. Weather Research Program (USWRP) and a 1997 NOAA Program Development Plan published by the University Corporation for Atmospheric Research (UCAR): "Weather and Climate Observing Systems: An Investment for America in the 21st Century."

   Benefits: This task leads directly to improved mesoscale weather services, that is, to better short-term predictions of disruptive weather events that today's observing systems and models have trouble capturing, for example: clusters of thunderstorms (their formation, influence on subsequent convection, and feedback to larger scales); excessive rainfall, localized fog and low ceilings; mountain-wave induced windstorms; bands of heavy snowfall embedded in widespread lighter snow; dividing lines between snow, sleet, freezing rain, and rain; cold-air damming.

· Develop near-term improvements to RUC and LAPS systems supporting improvements to quantitative precipitation forecasts (QPFs) and other forecasts for tactical planning (FY 2001 through FY 2004).

· Participate in development of the Weather Research and Forecasting (WRF) model with emphasis on the dynamics, physics, assimilation techniques, verification, and system infrastructure (FY 2001 through FY 2005).

· Validate the requirements and strategy for achieving the overall goal. Decide upon metrics for measuring progress. Develop a plan of action by the end of FY 2001 that demonstrates the feasibility of the project and explains the use of the Real-Time Verification System (RTVS) in tracking progress.

· Begin using the RTVS to track (possibly new) metrics that measure progress by the end of FY 2002.

· Help NOAA implement improved observing systems needed for better moisture and precipitation forecasts (FY 2002 through FY 2010).

· Implement a WRF-based Rapid Update Cycle at NCEP (FY 2005).

· Take advantage of next-generation, high-performance computers for advanced modeling/ assimilation systems (FY 2005).

The final four tasks are continuous throughout the project:

· Perform diagnostic modeling studies to further understanding of precipitation mechanisms, dynamical scale interactions, and numerical weather prediction model behavior.

· Tailor the use of observations and generation of guidance products for different operational organizations and user needs.

· Develop methods to convey these observations, products, and guidance to a variety of audiences (from forecasters to decision makers and the general public).

· Devise techniques to acquire, integrate, and manage the new technologies and infrastructure needed to accomplish this goal.

6) Explore new capabilities in high-performance computing technology, and develop new software tools for exploiting these new capabilities. Running prediction models at higher resolution, employing variational analysis in data assimilation (especially 4DVAR), and generating ensembles of forecasts, each places very heavy demands on computing systems. In meeting these demands, FSL sets two goals, one for procuring a next-generation computer and the other for developing tools to ease use of large software programs in the high-performance computing environment.

   Benefits: Maintaining leadership in the high-performance computing area benefits the public by improving the precision and accuracy of forecast models and supporting the evaluation of existing or proposed observing systems. The public and private sectors alike benefit from FSL's development of cost-effective computing solutions, as these cutting-edge technologies are transferred to entities outside the laboratory.

· Procure next-generation computer.
  – Investigate emerging technologies in the high-performance computing field. Develop requirements for the HPTi follow-up system (FY 2001).
  – Begin procurement process for follow-up system (FY 2002).
  – Have approved follow-up funding to execute procurement plan (FY 2004).
  – New computer is operational (FY 2005).

· Monitor developments in high-performance computing and develop appropriate software support strategies.
  – Parallelize the Rutgers ocean model, the Aeronomy Laboratory's air quality model, and the Taiwan Central Weather Bureau's typhoon model (FY 2001).
  – Ensure that the WRF model operates correctly in parallel mode on the HPTi parallel computer.

6. Management Strategy – Striking a Balance

- *Base funding versus outside (reimbursable) funding.* In recent years, base funding has been somewhat less than half of total funding. Base funding is, to some extent, discretionary; it allows the laboratory to begin projects that anticipate future service requirements, in advance of the time that outside funding can be attracted. Outside funding facilitates technology transfer but doesn't necessarily support forward-looking programs. Sometimes the effort to secure reimbursable funding is disproportionate to the potential gain; therefore, FSL will endeavor to increase base funding as a percentage of the total.

- *Mix of government, Cooperative Institute, and contract employees.* By federal regulation, certain functions of a laboratory must be performed by government employees, yet non-government employees are integral to the laboratory's viability. Cooperative Institutes supply a professional, scientific workforce and foster university interactions, which is highly desirable because universities connect FSL with fundamental research. Commercial affiliates supply much of the support for computing and systems administration. The contracting process enables FSL to support the laboratory infrastructure, keep pace with rapidly changing technology, and adapt to changing mission needs. FSL sees no compelling reason to change the current mix of employees (roughly 40% Civil Service, 33% Joint Institute, 20% commercial affiliates, and 7% other).

- *Laboratory size*. FSL emphasizes "end-to-end systems." Projects at FSL span the spectrum from the design and implementation of observing systems through data ingest, quality control, data assimilation, modeling, development of display systems, and provision of high-performance computing tools, to custom tailoring and dissemination of information to end users. Over the years, FSL has cultivated critical skills in each of these areas and managed to collocate them under a single roof. The number of laboratory employees has stabilized at about 200, and is commensurate with the laboratory's mission of technology transfer.

- *Balance between exploratory development and support to operations*. FSL's original charter emphasized exploratory development but did not include support to operations. Experience has demonstrated that successful technology transfer occasionally requires direct support to operations. Three examples are AWIPS, the RUC, and the NOAA Profiler Network, all of which FSL continues to support. FSL will emphasize exploratory development in the future, but not to the exclusion of support to operations where such support is critical to successful technology transfer.